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(54) AN ARTICLE HAVING A LOW COEFFICIENT OF FRICTION HYDROPHILIC COATING AND A METHOD OF PROVIDING THE COATING

(71) We, BIOSEARCH MEDICAL PRODUCTS INC., a corporation organized under the laws of the State of New Jersey, United States of America, of 77 Tillman Street, Raritan, New Jersey 08869, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:-

For numerous applications, particularly in the medical, veterinary and biological fields, such as contact lenses, catheters peristaltic pump chambers, condoms, implant materials, arteriovenous shunts, gastroenteric feed tubes and endotracheal tubes it is desired to have a material such as a polyurethane, acrylic polyester, or a vinyl resin or a rubber having a much lower coefficient of friction when wet than is possible with those materials per se.

In the prior art polyvinylpyrollidone has been chemically grafted to a polymer substrate by first activating the substrate by irradiation or chemically. The resultant coating does not have a very low coefficient of friction. Polyurethane coatings are well known, but do not have a very low coefficient of friction. Heretofore, polymer substrates have been given a lower coefficient of friction by coating them with a non-permanent coating such as silicone or given a fluorocarbon coating neither of which is hydrophilic and which do not have as low a coefficient of friction as desired. Also fluorocarbon coatings are hard to handle because they have a low coefficient of friction at all times.

These problems have been solved surprisingly by this invention by providing a coating of polyvinylpyrollidone-polyurethane interpolymer. The hydrophilic coatings of this invention are advantageous since they have a very low coefficient of friction when wetted with a water base liquid or a lower aliphatic alcohol such as methanol or ethanol and yet are much less slippery when dry. This is an advantage, for example, in the handling of catheters since it is desirable to have them not slippery for handling but protecting the patient by becoming slippery when contacting an aqueous fluid. This is an important advantage of the invention in view of the high degree of lubricity of the coatings. Further, the coating thickness is not limited to a few molecular monolayers as in the case of other methods such as chemical or radiation grafting and may be applied in thicknesses of several hundred micrometers. In addition for medical veterinary and biological applications the coatings are preferably non-reactive with respect to living tissue and are non-thrombogenic when in contact with blood.

In one aspect the invention comprises an article with a hydrophilic coating of polyvinylpyrollidone-polyurethane interpolymer.

In another aspect the invention comprises a method of providing an article with a hydrophilic coating which comprises providing an intermediate layer of polyurethane having unreacted isocyanate groups and then reacting that intermediate layer with polyvinylpyrollidone to provide a polyvinylpyrollidone-polyurethane interpolymer coating on the article. Suitably, the intermediate layer is provided by applying a solu-

tion containing a polyurethane and a polyisocyanate (or in the case where the article comprises a polyurethane surface applying a solution containing a polyisocyanate) and evaporating the solvent, and suitably the reaction of the intermediate layer with the polyvinylpyrollidone is effected by applying a solution of polyvinylpyrollidone and evaporating the solvent.

While the substrate may be any material to which conventional polyurethane coatings adhere, it is preferred to use polymer substrates such as a polyurethane resin, a vinyl resin (such as polyvinylchloride), a polyacrylate (such as polymethylmethacrylate), a polycarbonate, a polyester (such as polyethylene terephthalate, polybutylene terephthalate, or polytetramethylene terephthalate), or a rubber (such as latex rubber or polyisoprene).

The method of the invention comprises applying a polyisocyanate and a polyurethane (or polyisocyanate alone where the substrate is a polyurethane) in a solvent to the surface of the substrate to be coated with the interpolymer by, for example dipping or spraying and then evaporating the solvent preferably by air drying. This step forms a polyurethane coating with unreacted isocyanate groups on the substrate. Exemplary of the polyisocyanate are polymethylenepolyphenyl isocyanate, 4,4'-diphenylmethane diisocyanate and position isomers thereof, 2,4-tolylene diisocyanate and position isomers thereof, 3,4-dichlorophenyl diisocyanate and isophorone isocyanate. Adducts or prepolymers of isocyanates and polyols such as the adduct of trimethylolpropane and diphenylmethane diisocyanate or tolylene diisocyanate are suitable. For further examples of polyisocyanates see *Encyclopedia of Polymer Science and Technology*, H.F. Mark, N.G. Gaylord and N.M. Bikales (eds.) (1969). Exemplary of the polyurethane is the reaction product of 2,4-tolylene diisocyanate and position isomers thereof, 4,4'-diphenylmethane diisocyanate and position isomers thereof, polymethylenepolyphenyl isocyanate, or 1,5-napthylene diisocyanate with 1,2-polypropylene glycol, polytetramethylene ether glycol, 1,4-butanediol, 1,4-butylene glycol, 1,3-butylene glycol, poly(1,4-oxybutylene) glycol, caprolactone, adipic acid esters, phthalic anhydride, ethylene glycol, 1,3-butylene glycol, 1,4-butylene glycol or diethylene glycol. (For further examples see *Encyclopedia of Polymer Science and Technology* cited above). Chain extenders with hydrogen-containing difunctional compounds such as water, diamines, or amino acids may be used. Chain extenders are exemplified by 1,4-butanediol, hexamethylene diamine, 4,4-methylene-bis(2-chloroaniline) (MOCA), trimethylolpropane, and ethanolamine. Other additives include for example accelerators, catalysts, stabilizers or plasticizers, which improve or modify the properties of the urethane. Exemplary are dicumyl peroxide, benzothiazyldisulfide, mercapto benzothiazole, benzothiazole disulfide, polypropylene adipate, and metal salts such as potassium acetate, cobalt naphthenate, and zinc chloride.

The solvent is one which will not react with the isocyanate, i.e. it should be free of reactive amino, hydroxyl and carboxyl groups. Preferred solvents are dichloromethane, methyl ethyl ketone, acetone, ethyl lactate, chloroform, trichloroethylene and ethyl acetate. The hydroxyl of the ethyl lactate is not sufficiently reactive to be detrimental.

Preferred polyurethanes are polytetramethylene ether glycol-diphenylmethane diisocyanate (MDI), polytetramethylene ether glycol-tolylene diisocyanate (TDI), polytetramethylene ether glycol-isophorone isocyanate, poly(1,4-oxybutylene) glycol-diphenylmethane diisocyanate (MDI), poly(1,4-oxybutylene) glycol-tolylene diisocyanate (TDI), poly(1,4-oxybutylene) glycol-isophorone isocyanate, polyethylene glycol-diphenylmethane diisocyanate (MDI), polyethylene glycol-tolylene diisocyanate (TDI), polyethylene glycol-isophorone isocyanate, polypropylene glycoldiphenylmethane diisocyanate (MDI), polypropylene glycol-tolylene diisocyanate (TDI), polypropylene glycol-isophorone isocyanate, polycaprolactone-diphenylmethane diisocyanate (MDI), polycaprolactone-tolylene diisocyanate (TDI), polycaprolactone-isophorone isocyanate, polyethylene adipate-diphenylmethane diisocyanate (MDI), polyethylene adipate-tolylene diisocyanate (TDI), polyethylene adipate-isophorone isocyanate, polytetramethylene adipate-diphenylmethane diisocyanate (MDI), polytetramethylene adipate-tolylene diisocyanate (TDI), polytetramethylene adipate-isophorone isocyanate, polyethylene-propylene adipate-diphenylmethane diisocyanate (MDI), polyethylene-propylene adipate-tolylene diisocyanate (TDI), and polyethylene-propylene adipate-isophorone isocyanate polyurethanes.

Advantageously the polyisocyanate in the solution will be from 0.4% to 5% (weight to volume - W/V), preferably from 0.4% to 3% (W/V) and the polyurethane advantageously will be from 0.3% to 10% (weight to volume) preferably from 0.3% to 4% (W/V).

While the substrate generally need be in contact with the solution only briefly, for example 1 to 4 minutes, in the case of a rubber latex substrate a longer period of

from 15 to 120 minutes or more is desirable to achieve firm adherence of the final interpolymer coating to the rubber latex. Also with a rubber latex substrate a pretreatment step of soaking the rubber latex in a suitable solvent such as a chlorinated hydrocarbon solvent, for example, methylene chloride, chloroform, 1,1,1-trichloroethane, and ethylene chloride, for example from 15 to 120 minutes or more, to swell the rubber is advantageous.

The thus treated substrate is then coated with polyvinylpyrollidone in a solvent to form a polyvinylpyrollidone-polyurethane interpolymer. The polyvinylpyrollidone advantageously has an average molecular weight of at least 120,000 with the preferred average molecular weight being about 360,000. Exemplary of suitable solvents are chloroform, trichlorethylene, ethylene dichloride, methylene chloride and ethyl lactate. The solvent selected will be unreactive with the substrate. The polyvinylpyrollidone in the solution advantageously will be from 0.5% to 10% and preferably from 1% to 4% (weight to volume). While more than 10% of polyvinylpyrollidone can be used, no advantage is gained. The polyvinylpyrollidone in the solvent is applied by e.g. dipping or spraying for a short period, for example from 1 to 4 minutes. After the polyvinylpyrollidone solution has been applied to the coated substrate, the solvent is evaporated preferably by air drying. Advantageously the residual traces of solvent are removed by subjecting the coated substrate to a temperature of from 50° to 100°C., for example, in an oven. There remains a polyvinylpyrollidone-polyurethane interpolymer coating film on the substrate which when wet has an extremely low coefficient of friction and is hydrophilic.

If the substrate is of polyurethane, then the polyurethane in the solution may be eliminated and only the polyisocyanate need be used while carrying out the first step of the above described method.

All steps are carried out at room temperature except where otherwise specified.

The following Examples more specifically illustrate the invention:

Example 1

(1) A clean rubber latex urinary catheter is placed in dichloromethane and allowed to swell for 1 hour.

(2) The catheter is removed from the dichloromethane and dipped immediately into a methyl ethyl ketone solution containing 2% (weight/volume) of equal weights of a 32% (weight/volume) solution of polycaprolactone-tolylene diisocyanate polyurethane in ethyl acetate (commercially available from Hughson Corporation under the Trade Mark Chemlock 7000) and a 40% (weight/volume) solution of the adduct of trimethylolpropane-diphenylmethane diisocyanate in methyl ethyl ketone (Chemlock 7200 Trade Mark). The catheter is allowed to remain in the solution for 1 hour.

(3) The catheter is removed and air dried for 3 minutes.

(4) Step 2 is repeated but only for 4 seconds.

(5) Step 3 is repeated.

(6) Steps 4 and 3 are repeated.

(7) The catheter is dipped into a 4% solution (weight to volume) of polyvinylpyrollidone (M.W. 360,000) dissolved in ethyl lactate for 5 seconds.

(8) The catheter is removed and air dried. The dry catheter is cured in an oven at 65°C. for 6 hours.

(9) The catheter is removed from the oven. All steps carried out at room temperature except where specifically stated otherwise.

Example 2

(1) A peristaltic pump tube of polytetramethylene ether glycol-diphenylmethane diisocyanate (MDI)-polyurethane (available under the Trade Mark Roylar E85 from Uniroyal Chemical, Division of Uniroyal, Inc., Maugatuck, Connecticut) is dipped into a 1% solution (weight/ volume) of diphenylmethane diisocyanate (MDI), (available from Upjohn under the Trade Mark Isonate 143 L) in methyl ethyl ketone for 1 minute.

(2) The polyurethane tubing is removed and air dried until the MEK solvent evaporates.

(3) The polyurethane tubing is dipped into a 3% (W/V) solution of polyvinylpyrollidone in chloroform for 1 minute.

(4) The tubing is air dried and then oven cured for 1 hour at 75°C.

All steps carried out at room temperature unless specifically stated otherwise.

Figure 1 is a plan view of a condom in accordance with the invention;

Figure 2 is a fragmentary view of the condom of Figure 1;

Figure 3 is a modified condom in accordance with the invention;

Figure 4 is a fragmentary view of the condom of Figure 3;

Figure 5 is a modified condom in accordance with the invention;

Figure 6 is a fragmentary view of the condom of Figure 5;

Figure 7 is a plan view of a cardiovascular catheter partially broken away;

Figure 8 is a plan view of a peristaltic pump tube partially broken away; and

Figure 9 is a plan view of a urethral catheter partially broken away.

A condom 2 in accordance with the invention is shown in Figure 1. As best seen

in Figure 2, condom 2 has a base material or substrate 4 of polyisoprene the exterior of which is coated with a coating 8 of polyvinylpyrollidone-polyurethane interpolymer. The base material is secured to the conventional rubber band 10 at the inner end of condom 2.

A condom 12 shown in Figure 3 has, as best seen in Figure 4, a base material or substrate 14 of polyurethane provided with an outer layer of polyvinylpyrollidone-polyurethane interpolymer 16.

The condom 20 shown in Figure 5 has, as best seen in Figure 6, a base layer or substrate 22 of rubber latex to which is secured a film 26 of polyvinylpyrollidone-polyurethane interpolymer.

As shown in Figure 7, a cardiovascular catheter 30 is formed from a tubular member 32 of polyvinylchloride having a reduced tip end 34 coated with a layer 36 of polyvinylpyrollidone-polyurethane interpolymer.

As shown in Figure 8 a peristaltic pump tube 40 of polyvinylchloride is coated with a layer 42 of polyvinylpyrollidone-polyurethane interpolymer.

As shown in Figure 9, a urethral catheter 46 has a tip 48, a balloon portion 50, a drain connector 54 and a valve branch 56 formed from a branched tube 58 of rubber latex coated with a polyvinylpyrollidone-polyurethane interpolymer 60. An inflation valve 62 is secured to valve branch 56.

It will be understood that the above described embodiments are merely illustrative.

WHAT WE CLAIM IS:-

1. A method of providing an article with a hydrophilic coating which comprises providing an intermediate layer of polyurethane having unreacted isocyanate groups and then reacting that intermediate layer with polyvinylpyrollidone to provide a polyvinylpyrollidone - polyurethane interpolymer coating on the article.

2. A method as claimed in claim 1 wherein the reaction of the intermediate layer with the polyvinylpyrollidone is effected by applying a solution of polyvinylpyrollidone and evaporating the solvent.

3. A method as claimed in claim 1 or 2 wherein the article comprises a polymeric surface.

4. A method as claimed in claim 1, 2 or 3 wherein the intermediate layer is provided by applying a solution containing a polyurethane and a polyisocyanate and evaporating the solvent.

5. A method as claimed in claim 3 wherein the polymeric surface is of polyurethane and the intermediate layer is provided by applying a solution of a polyisocyanate and evaporating the solvent.

6. A method of placing on a substrate a hydrophilic coating which has a low coefficient of friction when wetted with a water based liquid comprising: applying to the substrate a solution having from 0.4% to 5% (weight to volume) polyisocyanate and from 0.3% to 10% (weight to volume) polyurethane, evaporating the solvent, applying a solution of polyvinylpyrollidone having from 0.5% to 10% (weight to volume) to the thus treated substrate and then evaporating the solvent of the last mentioned solution to form a polyvinylpyrollidone-polyurethane interpolymer.

7. A method as claimed in claim 6 in which the polyisocyanate is from 0.4% to about 3% and the polyurethane is from 0.3% to 4% (weight to volume) of the first mentioned solution and the polyvinylpyrollidone is from 1% to 4% (weight to volume) of the second mentioned solution.

8. A method of placing on a polyurethane substrate a hydrophilic coating which has a low coefficient of friction when wetted with a water based liquid comprising: applying to the substrate a solution having from 0.4% to 5% (weight to volume) polyisocyanate, evaporating the solvent, applying a solution having from 0.5% to 10% (weight to volume) polyvinylpyrollidone to the thus treated substrate and then evaporating the solvent to form a polyvinylpyrollidone polyurethane interpolymer.

9. A method as claimed in claim 8 in which the polyisocyanate is from 0.4% to 3% (weight to volume) of the first mentioned solution and the polyvinylpyrollidone is from 1% to 4% (weight to volume) of the second mentioned solution.

10. An article comprising: a substrate, and a polyvinylpyrollidone-polyurethane interpolymer coating on said substrate.

11. An article as claimed in claim 10 in which the substrate is a polymer.

12. An article as claimed in claim 10 or 11 in which the substrate is of polyurethane.

13. An article as claimed in claim 10 or 11 in which the substrate is of a material other than polyurethane coated with a film of polyurethane.

14. An article as claimed in any one of claims 10 to 13 in which the substrate is a condom and the coating is on the outside of the condom.

15. An article as claimed in any one of claims 10 to 13 in which the substrate is a tube and the coating is on the outside of the tube.

16. An article as claimed in any one of claims 10 to 13 in which the substrate is a catheter and the coating is on the outside of the catheter.

17. A method of providing an article with a polyvinylpyrollidone-polyurethane interpolymer coating substantially as

hereinbefore described with particular reference to Example 1.

18. A method of providing an article with a polyvinylpyrollidone-polyurethane interpolymer coating substantially as hereinbefore described with particular reference to Example 2.

19. An article coated with a polyvinylpyrollidone-polyurethane coating substantially as hereinbefore described.

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1600963 COMPLETE SPECIFICATION

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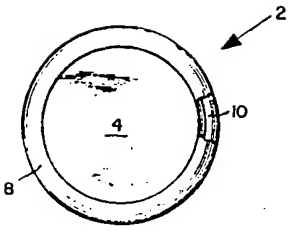


FIG. 1.

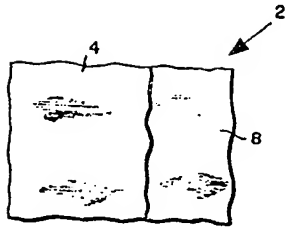
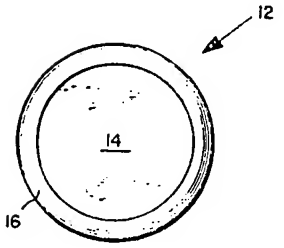


FIG. 2.



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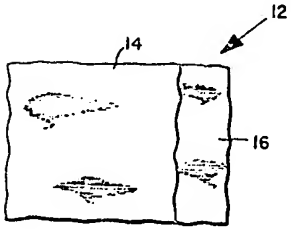

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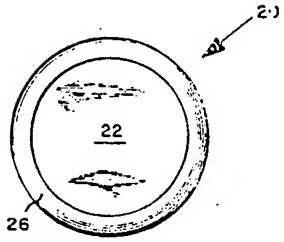

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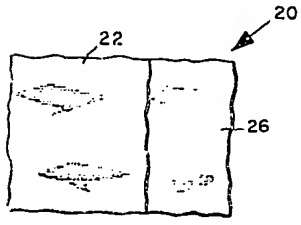

FIG. 6.

1600963 COMPLETE SPECIFICATION
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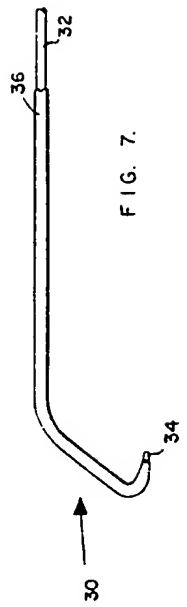

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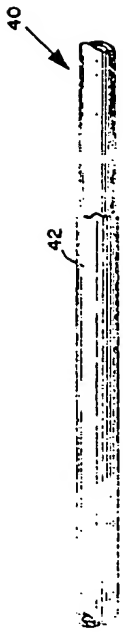

FIG. 8.

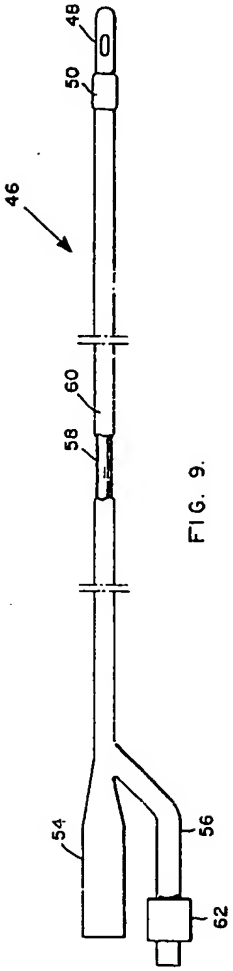

FIG. 9.

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